HF radar in French Mediterranean Sea: an element of MOOSE Mediterranean Ocean Observing System on Environment

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Abstract. In the framework of the French MOOSE project (Mediterranean Ocean Observing System on Environment), the Mediterranean Institute of Oceanography is operating HF radars on the North Western Mediterranean coast. The surface circulation in this region is characterized by a large-scale flow (Northern Current) and by a broad range of other scales of variability induced by meteorological and tidal forcing. The ability of HF radars is to provide synoptic observation as sea surface current map every hour and over long distances. One site is already operational nearby Toulon for more than two years and a second one is in deployment around Nice. This paper gives an overview of the radars network, of the surface current mapping facility offered by the system, and of recent observation results and applications.

1 INTRODUCTION

The MOOSE concept is based on Eulerian observatories and autonomous mobile platforms to support the Mediterranean observation. The main objectives are to observe the long-term evolution of the NW Mediterranean Sea in the context of climate change and anthropogenic pressure and to supply and maintain long-term time series, which are the only relevant data to evidence climatic trends and identify long-term environmental anomalies.

Today, High Frequency Surface Wave Radar (HFSWR) is routinely used for the remote sensing of the ocean surface. Current measurements are obtained from the Doppler shift of the first-order Bragg-resonant echoes ([Crombie, 1955, 681-682]). Recent oceanographic studies in the Gulf of Lion (NW Mediterranean) have shown the existence of vortex structures and instabilities in a wide range of scales. These properties of the coastal circulation have been well evidenced

in the context of the ECOLO campaign ([Schaeffer *et al.*, 2011, 1587-1609]), where a certain number of in situ and remote sensors have been collocated: SST and water color satellite imagery, satellite-based drifting buoy trajectories and radar derived surface currents.

Our laboratory (MIO) has proven its expertise in radar measurement of surface currents ([Broche *et al.*, 1987, 69-75], [Molcard *et al.*, 2009, s79-s89]) and has been assigned the task to deploy the HF radar network for the MOOSE program.

2 HF RADAR DEPLOYMENT IN NORTH WESTERN MEDITERRANEAN SEA

The chosen sites for this HF radar network have been identified in order to cover the regions of interest for the MOOSE program (*Fig. 1.*). The main difficulties for deploying HF radars lie in the hardware costs, the frequency licenses, and the site finding, especially when considered coast is irregular and steep or close to touristic and crowded regions.

The first target area off the coast of Toulon (ANTARES) is a key zone conditioning the behavior of the North Current (NC) downstream of the Gulf of Lions, and the exchanges across the shelf edges. This fully operational site is monitored by two Wellen Radar (WERA [Gurgel *et al.*, 1998, 219-234]) systems manufactured at Helzel Messtechnik GmbH and provide real-time data. The first radar system has been installed at the Cap Sicié in 2010 and works in monostatic configuration. In May 2012 it has been complemented with a second radar system working in bistatic configuration, with a receiver located at Cap Bénat and a transmitter on Porquerolles Island. This specific configuration has required some new processing adapted for bistatism ([Barbin, 2011]). It also allowed us to study the bistatism effects on the HF doppler spectra in realistic conditions and it shows good relevance for the purpose of wave spectrum inversion ([Grosdidier *et al.*, 2013]).

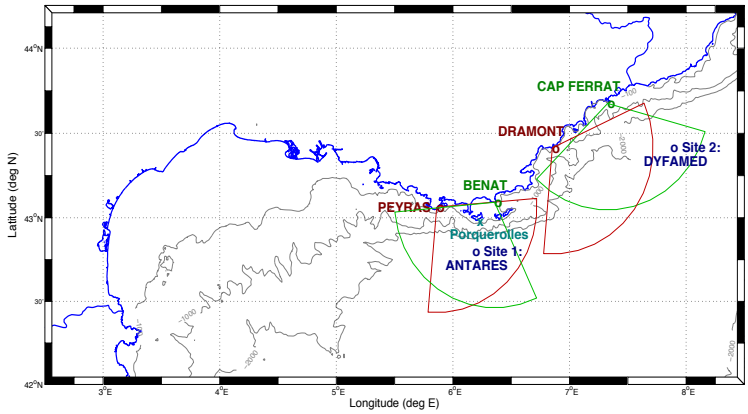

Fig. 1. Map of the HFSWR sites: *#1 ANTARES-TOULON, #2 DYFAMED/Ligure*. On *site 1 ANTARES*: the configuration is one monostatic radar at Cap Sicié (*Peyras*), one standalone transmitter on *Porquerolles* island, and its receiver at *Cap Bénat* (18 km far away). On *site 2 DYFAMED:* it will be covered with two radar seasondes, one located at *Cap Ferrat*, and the other at *Dramont.* The *arc of circles* show the approximate radar coverage area of each system

The upcoming implementation of a second HFSWR site, by the end of the year 2013, in the Ligurian area (DYFAMED) will extent the radar observation to the full coastal area between Toulon and Nice. This should allow to monitor seasonal and high frequency variability of the current across the North front and its interactions with the coastal circulation in the vicinity of the reference sites. The selected equipment to cover the DYFAMED area is a pair of more compact HF radar system, namely two SeaSondes from CODAR Ocean Sensors ([Barrick, 1979]).

The ever-increasing deployment of HFSW radars has led the community to look for new rules for frequency sharing. Our radars follow the ITU recommendations and operate in the frequency sub-band specified for oceanographic purposes, within only half of the hundred kHz ITU sub-bands.

3 FIRST RESULTS AND APPLICATIONS

HF radar-based measurements can provide a good description of the variability of the Northern current and are key element of the observatory network, which also includes also gliders and moored lines.

In the first step of the ANTARES implementation (2010-2011), one single radar was working at Peyras site and could only provide one radial component of the Northern Current. During this period, prior to the complete installation of the system with the second bistatic component Porquerolles-Bénat, even if it could provide only a partial information, the Vortex Identification Method (VIM) was successfully tested and revealed some eddy-like structures ([Marmain *et al.*, 2011, 1967-1979]). During the PHYOCE campaign (march 31st - april 3rd 2011), the radial velocities field from the one single radar allowed to described in surface the variability of the current flow and was used in complement to *in-situ* measurement to confirm the existence of coastal eddies acting at mesoscales which match with the numerical model of circulation GLAZUR-64 ([Guihou *et al.*, 2013, 793-808]). This leads that radar data assimilation is now conceivable.

Full vector current maps are now available since 2012. First results, as shown in *Fig. 2.*, confirm that radar measurements of surface currents are in good agreement with the structure revealed by the sea surface temperature remote sensed and are some good indicators of hydrodynamics structure. The radar data put in evidence the meso-scale structures and the interruption of the Northern current due to strong wind episodes ([Bellomo, 2013]).

During the TOSCA (MedProgram) campaign, a comprehensive data set of surface radial currents measured by HFSWR, surface drifter trajectories, and gliders was collected. The data gathered by the project have been combined into a web based decision tool designed for authorities in charge of maritime crisis. The system provide critical data and applications, as the visualization of the surface currents and dispersion of an oil spill.

The potential of this real-time observation lies also through the data assimilation, as it can correct the baroclinic oceanic forcings and improve the surface currents ([Marmain *et al.*, 2013]).

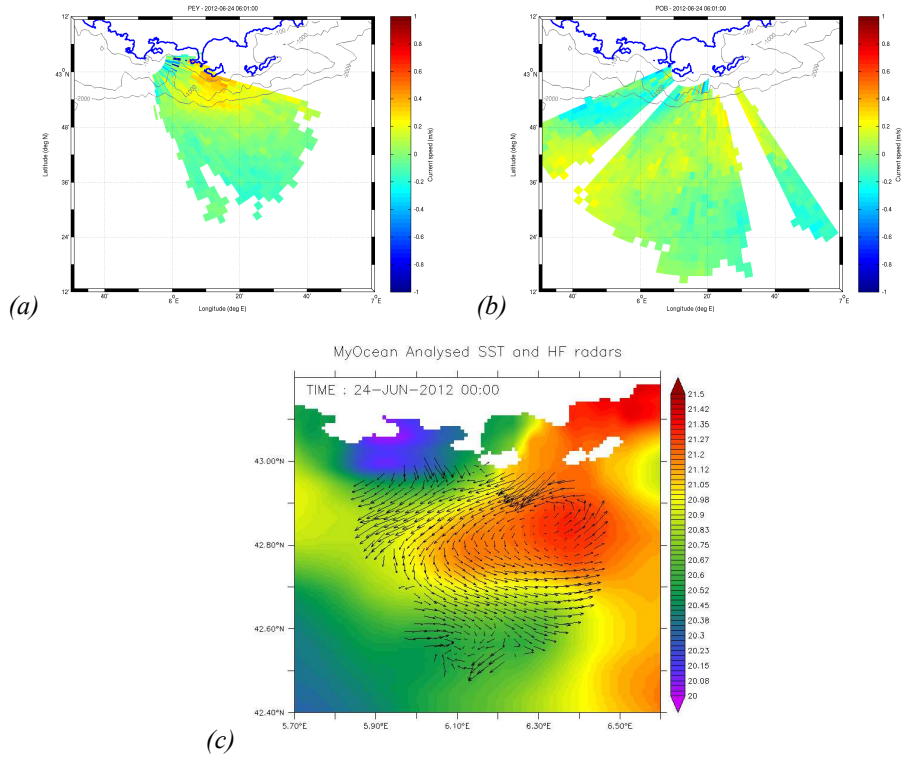

Fig. 2. On the top, the two *radial velocity* maps in color scale from *(a) on right Peyras, (b) on left Porquerolles-Bénat*. Positive values are going to the radar, and negative are coming from the radar. On the bottom *(c)*, the combination of the two radial maps gives the *surface currents* (*black arrows*) measured by HFSWR and the background image is the *sea surface temperature* (*colored pixels* product from "MyOcean": http://www.myocean.eu.org/). This illustrates a flow disturbed by the presence of a cyclonic vortex south of the North current

4 CONCLUSION

A network of HF radar is currently being deployed by the MIO. It should be very helpful to provide long-term current data of the French Mediterranean coastal area in the context of the MOOSE program. First results based on the already operated radar site are very promising and provide real time maps of the current vector. The HFSWR data can be viewed in real time on *http://hfradar.univ-tln.fr*

As the radar data are provided almost in real time, it gives the ability to schedule a scenario to have a precise sampling of the hydrodynamic structure with in-situ instrument (drifters, gliders or ADCP) deployed on asking. During the TOSCA project, which intends to optimize the response to marine accidents in Mediterranean sea, we demonstrate that the radar data assimilation represents a great advantage to describe with more accuracy surface currents.

HFSWR is a relevant tool to study the coastal dynamic circulation. HFSWR network needs to be deployed to have a permanent focus on the sea surface circulation and its

variability. The measurements could also be integrated into crisis management system. For this aim, it is important that the HFSWR network is constantly maintained and monitored.

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REFERENCES

Crombie, D. D. (1955). Doppler spectrum of sea echo at 13.56 Mc./s., Nature 175, (pp. 681 - 682). http://dx.doi.org/10.1038/175681a0

Schaeffer, A. Molcard, A. Forget, P. Fraunié, P. & Garreau P. (2011). Generation mechanism of mesoscale eddy in the Gulf of Lions: radar observation and modelling, *Ocean Dyn., vol. 61, Issue 10* (pp. 1587-1609). http://dx.doi.org/10.1007/s10236-011-0482-8

Broche, P. Forget, P., Maistre, J. C. D., Devenon, J.L. & Crochet M. (1987). VHF radar for ocean surface current and sea state remote sensing, *Radio Science, vol. 22,* (pp. 69-75).

Molcard, A. *et al.* (2009). Comparison between VHF radar observations and data from drifter clusters in the Gulf of La Spezia (Mediterranean Sea), *Journal of Marine Systems, vol. 78, Supplement*, (pp. S79-S89). http://dx.doi.org/10.1016/j.jmarsys.2009.01.012

Gurgel, K-W., Antonischki, G., Essen, H-H. & Schlick, T. (1998). Wellen radar (wera), a new ground-wave based HF radar for ocean remote sensing, *Coastal Engineering, vol. 37, Issues 3-4*, (pp. 219–234). http://dx.doi.org/10.1016/S0378-3839(99)00027-7

Barbin, Y. (2011). High Resolution Surface Currents Mapping using Direction Finding Method in Bistatic Radar Configuration, *Third Conference on Remote Ocean Sensing, La Spezia*.

Grosdidier, S., Forget, P., Barbin, Y. & Guerin, C.-A. (2013). Simulation of HF bistatic ocean radar system in experimental conditions, *IEEE Geosci. Rem. Sens., vol. 99*, in press.

Barrick, D. E. & Evans, M. W. (1979). CODAR: A coastal HF radar for real- time current mapping, *U. S. Patent 4 172 255*.

Marmain, J., Forget, P. & Molcard, A. (2011). Derivation of ocean surface current properties from a single-site HF/VHF radar, *Ocean Dynamics, vol. 61, num. 11* (pp. 1967-1979). http://dx.doi.org/10.1007/s10236-011-0461-0

Guihou, K. *et al.* (2013). A case study of the meso-scale dynamics in the North-Western Mediterranean Sea: a combined data-model approach, *Ocean Dynamics, JONSMOD 2012 Coll., vol.63, Issue 7, (pp 793-808).*

http://dx.doi.org/10.1007/s10236-013-0619-z

Bellomo, L. *et al* (2013). Observational evidence of mesoscale variability of the Northern Current (North-Western Mediterranean Sea): a combined study via gliders, HF RADAR, surface drifters, and vessel data, *European Geosciences Union General Assembly, Vienna, vol.15, Ocean Science 4.5*.
http://presentations.copernicus.org/EGU2013-5469_presentation.pdf

Marmain, J., Molcard, A., Forget, P. and Barth A. (2013). Optimization of boundary conditions of a North Western Mediterranean coastal zone using HF radar measurements, *ASLO 2013 Aquatic Sciences Meeting, New Orleans.*